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PETROLOGY.—*The development of pressure in magmas as a result of crystallization.*[1] GEORGE W. MOREY, Geophysical Laboratory.

The explanation of the phenomena which take place in the cooling of molten magmas, whether forming intrusive masses or extrusive flows, is one of the principal functions of petrology. To such magmas all of the laws of the physical chemistry of mixtures apply, and the phenomena met with as these mixtures cool and solidify under the conditions found in nature are the result of the action of these physico-chemical laws. The elucidation of these phenomena in terms of the known laws of physical chemistry is made difficult both by the extreme complexity of the natural mixtures and by the general lack of knowledge as to the theoretical relationships of mixtures containing not only non-volatile components such as the silicate minerals but also volatile components far above their critical temperatures, such as carbon dioxide and water.

In this note attention will be directed to certain relationships between the temperature and composition and the vapor pressure of the volatile component, and especially to the relations between these quantities at temperatures approximating to the temperature of anhydrous fusion of the mineral components, and at very considerable pressure. At temperatures near that at which crystallization begins a liquid silicate mixture containing but a small amount of volatile component may exert but a comparatively small vapor pressure, but as crystallization proceeds with falling temperature the pressure of the volatile components will increase at a rapid rate: so rapid that a pressure many times the original pressure may result from the crystallization of but a small proportion of the non-volatile material. This relation holds true whether the original liquid mixture consists of water and a low melting salt such as KNO_3, or of water and other volatile substances with the usual non-volatile magmatic constituents; the

[1] Received March 27, 1922.

circumstance that the magmatic liquid is at a temperature far above the critical temperature of the volatile ingredients is without significance as long as any of the liquid phase remains in the system. The system H_2O–KNO_3 has accordingly been chosen to illustrate the relations between the variables, pressure, temperature and composition in a system containing both volatile and non-volatile components.

In a system such as H_2O–KNO_3 it is well known that the solubility or fusion curve is continuous from the eutectic or cryohydrate to the melting point of each component. This is illustrated in figure 1, C,[2] in which E is the eutectic, or cryohydrate, A_mE the freezing-point curve of water in equilibrium with solutions of increasing KNO_3 content, B_mE the freezing-point curve of KNO_3 in equilibrium with solutions of increasing H_2O content. While with mixtures rich in KNO_3 it is necessary to carry out solubility experiments inclosed vessels to prevent the escape of the water, KNO_3 and water are both components of all liquids in the binary system. This still holds true when component B has a melting point above the critical temperature of water, as is the case in magmatic solutions. The curves showing the vapor pressure of the saturated solutions given in figure 1, C are likewise continuous from the eutectic to the melting point of components A and B, respectively, and in the case of the solutions in equilibrium with the component of higher melting point, KNO_3, the curve must rise to a maximum pressure with increase in temperature, then on further increase in temperature the pressure must fall to the vapor pressure of the higher melting component at its melting point, or, more exactly, its triple point. This is shown in figure 1, B, in which the curve EB_m is the vapor-pressure curve of the solutions saturated with component B. As the temperature is increased, the vapor pressure of the saturated solution is determined by the balance between two opposing tendencies. One of these is the increase in vapor pressure of the water with increasing temperature; this is opposed by the decreasing water content of the solutions, and at the point of maximum pressure the two effects become equal. At higher temperatures, the second effect preponderates, and the pressure of the saturated solution decreases with increasing temperature. The actual ratio of the non-volatile to the volatile component at the point of maximum pressure is equal to the

[2] Fig. 1 is drawn to scale for the system H_2O–KNO_3, but the components H_2O and KNO_3 are represented by A and B, respectively, for the purpose of clearer discussion of similar relations in systems containing other components. Experimental details of the study of this system will be published soon.

FIGURE 1. C.

Fig.

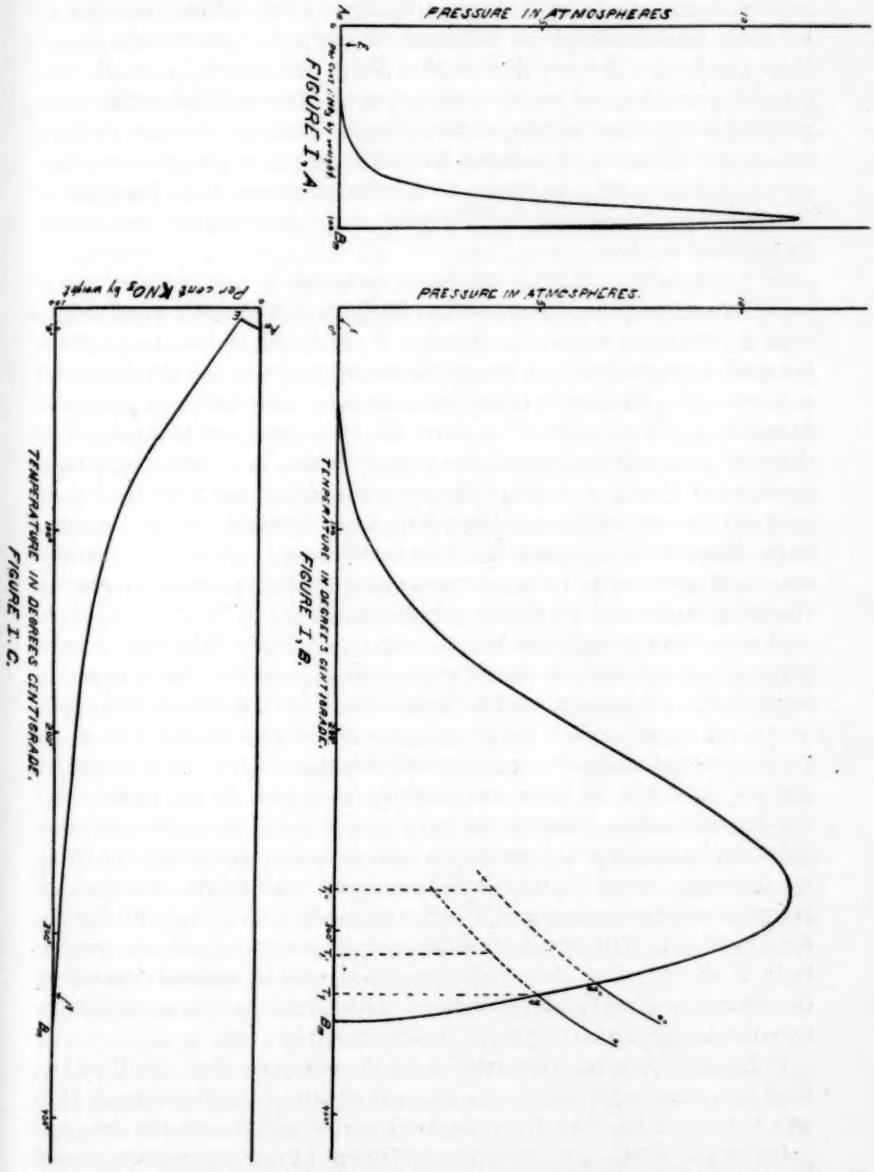

Fig. 1. Diagrams showing the change of the pressure, temperature, and composition of the univariant equilibria between solid, liquid, and vapor phases in the binary system H_2O–KNO_3.

ratio of the differential heat of vaporization to the differential heat of solution, and inasmuch as the former is always several times greater than the latter, the solution at this point will always contain but a small percentage of water; this is especially noticeable when composition is expressed as weight percentage, because of the low molecular weight of water. It follows from this fact that the pressure-temperature curve, EB_m in figure 1, B, will fall steeply from the point of maximum pressure to the melting point of the non-volatile component, in this case KNO_3.

In a binary system there are three variables to be considered, pressure, temperature, and composition of the liquid phase in equilibrium with crystals and vapor. In figure 1, C and B, are shown the relations between temperature and composition and between temperature and pressure; the relation between pressure and composition is shown in figure 1, A. The curve EB_m gives the vapor pressure of solutions of different composition in equilibrium with KNO_3 and vapor; the temperature to which a mixture of any composition must be heated to melt all but an infinitesimal portion of the crystals can be obtained from either B or C, figure 1. This curve shows in a striking manner the rapid increase in pressure consequent on but a small increase in the water content of the KNO_3 rich solutions.

If a mixture of composition y (figure 1, C) be considered at a temperature above that of the corresponding point on the saturation curve EB_m, its pressure will be represented by a point on the curve ay (figure 1, B). This curve ay gives the change in vapor pressure with temperature of the unsaturated solution of the composition y, and its slope will be large and positive, as shown in the figure. As the temperature is lowered the presssure will fall along the curve ay until the latter curve intersects the curve of saturated solutions EB_m. At this point crystallization will begin, and with further decrease of temperature the pressure will increase along curve B_mE in the direction of y''. The rapidity of increase in pressure, and the magnitude of the pressure ultimately developed, will in general depend on the solubility of water in the liquid. This effect may be made clearer by considering the matter from another point of view.

If liquid KNO_3 be cooled in an apparatus such that the liquid is kept in contact with steam at a pressure of one atmosphere, some H_2O will be dissolved, and this dissolved water will lower the freezing point of the KNO_3. If the pressure is kept at one atmosphere about 1 per cent of water will be dissolved, and it will lower the freezing point

of the KNO_3 about 3° C. With the liquid saturated at this temperature, suppose the apparatus to be closed in such a manner that the vapor space is very small, and the cooling to be continued, then crystallization of KNO_3 will begin at about 3° below its own freezing point. As the mixture cools, crystallization proceeds, the water content of the mixture increases, and its vapor pressure rises. Reference to figure 1, A or B, shows that at the time crystallization begins, the liquid composition is 99 per cent KNO_3, 1 per cent H_2O. When the water content has doubled, the pressure has increased from 1 atmosphere to over 6 atmospheres, a six-fold increase. When the water content has again doubled, reaching 4 per cent, the pressure has risen to almost 11 atmospheres. If the mixture be contained in a flask which can withstand a pressure of only 10 atmospheres, the flask will burst, as the result of the pressure developed by cooling the mixture.

Similar relations hold in silicate systems. It is now a demonstrated fact that water vapor under a pressure of one atmosphere is appreciably soluble in liquid silicates at their melting points, and that the amount of water dissolved at this pressure will produce an appreciable lowering of the melting point. In other words, the melting point as determined in steam at one atmosphere pressure is appreciably lower than that determined in air in the usual manner, just as was the case with KNO_3. In the case of anorthite, about 0.1 per cent of H_2O is dissolved, and the freezing point is lowered about 5°. If the initial pressure of water vapor is increased, more water will be dissolved and freezing will begin at a correspondingly lower temperature. In the case of KNO_3, increase in the water content from 1 to 4 per cent corresponded to an increase of pressure from about 1 to over 11 atmospheres. In the case of a system such as H_2O–SiO_2 the maximum pressure would probably be reached at a smaller H_2O content, and its magnitude would probably be enormous. Likewise, the pressure which would be developed by a magma containing but a small amount of H_2O, cooled in such a manner that this water could not escape, as is doubtless oftentimes the case, would be very great indeed.

Before considering this phase of the subject further, some known examples showing the reality of the phenomenon will be given. When liquid KNO_3 is saturated with water at one atmosphere pressure, and the mixture cooled, at a certain temperature solid KNO_3 will begin to separate from the liquid. If the vessel be open to the air, the pressure cannot rise above one atmosphere, so the water will pass off as steam; the liquid will evaporate to dryness, giving rise to solid and

vapor. Roozeboom gave the name "second boiling point" to this higher boiling point, which is obtained on cooling as above described. The second boiling point of a number of salt solutions has been observed by Smits, and others have been observed by the author. The" spitting" observed when molten silver is cooled in air is another example of the second boiling point, in this case in the system silver–oxygen, and a similar "spitting" was observed by Prandtl and Murschauser[3] with alkali vanadates. Jackson[4] gives an interesting description of a gas evolution on cooling on a much larger scale, which will be quoted:

"* * * * * * For a special optical glass, rich in phosphoric anhydride, an experiment was tried with ammonium phosphate to find if this substance could be used in the batch mixture for the glass. A nice, clear fluid melt was obtained, which was kept fluid for several hours after all traces of gas bubbles had gone. The melt was well stirred and cooled till it was quite viscous, when it was left to get cold slowly. The next morning the furnace top was found forced off, and resting on a spongy mass of about thirty times the volume of the original glass melt. The changes occurring when solidification was approaching had evidently been accompanied by the evolution of a large volume of gas, no doubt most of it ammonia, since this substance was smelt on grinding the spongy mass up. The ground material was then fused and gave a stable glass." This is probably to be explained by partial crystallization of the glass in the pot.

Experimental data exist for but one system which can fairly be taken as analogous to mineral systems, the system H_2O–K_2SiO_3–SiO_2.[5] The cooling of certain mixtures in this system will next be considered. With some compositions the second boiling point at atmospheric pressure can be demonstrated in a striking manner. If potassium metasilicate at its melting point be saturated with water at one atmosphere pressure, it takes up about 1 per cent, enough to lower its melting point about 35°. If the saturated liquid be cooled quickly it becomes supersaturated; the molten aqueous glass remains liquid until cooled several degrees below its melting point. First a few bubbles begin to form within the glass; then suddenly the bubble formation becomes rapid, the viscous melt swells into a pumiceous mass, increasing in volume many times, and overflowing the crucible. This is an example of the second boiling point at atmospheric pressure; of a boiling,

[3] Zeit anorg. Chem. **56:** 173–208. 1908.
[4] Sir HERBERT JACKSON, Smithsonian Report for 1919, p. 245.
[5] MOREY AND FENNER. Journ. Am. Chem. Soc. **39:** 1173–1229. 1917.

attended by sudden liberation of vapor, taking place as a result of cooling.

A further example, illustrating, from the experimental results, the development of a fairly high pressure in a silicate system as the result of cooling, may be found in the same system. The eutectic between $K_2Si_2O_5$ and SiO_2 lies at the remarkably low temperature of 520°. If a mixture of K_2O, SiO_2 and H_2O, containing 9.1 per cent of H_2O, with the other ingredients in the molecular ratio SiO_2/K_2O = 4.26, be cooled from a high temperature, the vapor pressure of the mixture will fall as the temperature falls. The mixture will not begin to freeze until it has cooled to 500°, when crystals of quartz and the ternary compound $KHSi_2O_5$ will separate. The vapor pressure of the solution at this temperature is 160 atmospheres. On further cooling, the substances continue to crystallize and the pressure increases rapidly. When the temperature has fallen 20°, to 480°, the water content has increased to 10.2 per cent, and the pressure to 180 atmospheres. When the temperature has fallen to 420°, the water content has increased to 12.5 per cent, and the pressure to 340 atmospheres, more than double the pressure at 500°.

In discussing the crystallization of this mixture, it was assumed that crystallization started at 500°, the saturation temperature of the mixture, and the pressure rose from 160 atmospheres to 340 atmospheres continuously as the mixture crystallized on cooling. It is of interest to consider what would happen if the mixture were to cool without crystallizing, say to 420°, and then begin to crystallize. In figure 1, B, the curve *ay*, giving the change in pressure with temperature of the mixture of composition *y* in figure 1, C, is shown cutting the curve EB_m at a sharp angle; its metastable prolongation, shown broken in the figure, gives the change in vapor pressure that would take place if the mixture failed to crystallize. It is safe to assume that this curve has a steep slope. Similarly, if the mixture in the ternary system were to supercool, its pressure would diminish rapidly, and the amount of the diminution can be estimated. The vapor phase consists of water only at a pressure of 160 atmospheres. Pure water has a vapor pressure of 160 atmospheres at 348°, and it is probable that the two vapor-pressure curves will be roughly parallel, with the curve of the saturated solution possibly falling more rapidly than that of pure water. On the assumption that the drop in pressure for the 80° drop in temperature from 500 to 420° in the solution is the same as the drop in pressure of water from 348° to a temperature 80° lower, the vapor pressure of

the supercooled liquid at 420° will be 59 atmospheres. If the mixture containing 9.1 per cent water were to cool, without crystallizing, from 500°, its saturation temperature, to 420°, its pressure would fall from 160 atmospheres to about 50 atmospheres. If at this lower temperature it should begin to crystallize the pressure would suddenly rise to that of the solution in equilibrium with quartz and $HKSi_2O_5$ at 420°, or 340 atmospheres.

It is evident, then, that as a magma containing water and other volatile components cools, with consequent crystallization, the pressure will rapidly rise from its initial value, and as the cooling continues the pressure will increase until the temperature of maximum pressure has been reached, or until the pressure is relieved by escape of the volatile material. In the first case, which is that in which the liquid cools under a crust of sufficient weight and strength to withstand the internal pressure, the liquid will solidify as an intrusive mass. In the case of an actual magma the fact that water has a critical temperature at 374° C. has no significance, because of the probability that enough material will remain in solution to raise the critical temperature of the mixture the requisite amount. The water, containing in solution residual material such as dissolved gases, boric acid, sulfur, and probably some alkalies, will be available for metamorphic processes.

In the second case, that in which the liquid cools under an incompetent crust, when the pressure has reached a certain limiting value it will force open a vent for itself, possibly giving rise to a volcanic eruption. The phenomenon observed in any particular eruption will depend, in large part at least, on the magnitude of the pressure and on the composition of the non-volatile portions of the magma, though these factors may not be independent. If the vent is a fairly open one, enormous pressures probably will not be developed and the escape of the water as steam may be comparatively quiet; this will presumably be the more probable in the case of a very fluid lava. The mild explosive activity of Stromboli and the yet milder bubbling of Kilauea may be examples of this type. It may well be that in both these cases the activity is the result of the release of volatile material consequent on crystallization, and the rate of release of the volatile material may be regarded as a measure of the rate of crystallization in the parent body. The difference in violence in the two cases may be determined solely by the depth at which crystallization is taking place, and by the size or tortuosity of the channel through which the material must pass.

On the other hand, conditions may be such that a much greater pressure must be developed before the gases are able to force their way to the surface. It may be assumed that eruptions will then take place at less frequent intervals, since more time must elapse for the cooling process which occasions the crystallization, and that, on account of the greater pressure, the resulting eruptions will tend to be catastrophic. In a previous paragraph it was stated that in the case of an incompetent crust the building up of pressure as the result of cooling and crystallization would continue until the pressure was relieved by the escape of the volatile material. It might be that, if the crust were of sufficient strength, a fairly large proportion of the liquid magma would crystallize before a pressure had been built up of sufficient magnitude to cause an eruption. These conditions may determine the formation of a new volcano, such as Monte Nuovo, Jorullo, or Chinyero, and may also explain the renewed activity of a volcano whose vent has been plugged by solidified lava. In such a case, in which a considerable amount of crystallization has taken place, the non-crystallized material ejected will represent the "mother liquor" remaining after the segregation of those minerals which are the first to crystallize under the conditions prevailing. These may be the femic minerals; in which case the mother liquor will be enriched in the more salic minerals, quartz and the feldspars, and the water content will be correspondingly increased.[6] The tendency for the heavier femic minerals to differentiate by settling will be great, especially since the density difference between the femic and salic minerals will be increased by the presence in the salic melt of the accumulated water. We should therefore expect, irrespective of the original composition of the magma, that paroxysmal eruptions would be characterized by the ejection of salic lava. The presence or absence of traces of the differentiated materials will be erratic, depending on the completeness of the differentiation in relation to the original situation of the material examined. Moreover, since the salic lavas are in themselves, when freed from water, viscous even at their melting points, and since the temperature at this stage will have been greatly lowered, on the sudden expansion following the disruption of the restraining crust, the ejected material will be shattered into small fragments. It will be seen that the above conclusions are in accord with the well-known characteristics of catastrophic eruptions; salic

[6] N. L. BOWEN. *The later stages of the evolution of the igneous rocks.* Journ. Geol., Suppl. to Vol. **23**, No. 8. 1915.

ejecta, highly vesiculated, containing large amounts of glassy material, ejected by violent explosions following long periods of quiescence. The well-known cases of Bandai-San, Krakatoa, and Martinique may be cited as illustrations. Material ejected from Krakatoa "was so vesicular that it floated in the water, accumulating here and there in great banks which covered the sea for miles, rising sometimes to a height of four or five feet above it,"[7] and the ejecta still contained considerable water, as well as much glassy material.

In the above discussion the question of the source of the water has not been considered. Doubtless the original magmas contain water, but whether or not this is augmented by accession of meteoric water is an open question. The often cited proximity of active volcanoes to large bodies of water may be regarded as evidence of the probability of such accession, and in some instances the case for the absorption of meteoric water is strong, but it may not be true in the majority of cases. It has been demonstrated by Johnston and Adams[8] that the phenomenon of capillarity does not furnish a mechanism for the introduction of water into magmas, and they have shown that the often cited Daubree experiment has no bearing on the question at issue. As previously stated, crystallization and differentiation will result in the accumulation of water in the residual magma, and such accumulation probably is competent to explain the production of those pitchstones which contain water sometimes up to 10 per cent. Irrespective of the relative importance of original and meteoric water, it is believed that the relations which have been outlined furnish a mechanism by which water can enter a magma. Not only is it possible for a magma to take up water, but the water may be taken up by the magma under a small pressure head and later liberated with the development of high pressure.

It has already been shown that in a crystallizing magma the water accumulates in the liquid phase. If a magma, either deficient in water or containing but a small amount of water, and above its crystallizing temperature, be in contact with porous water-containing strata, it will absorb water vapor until its water content corresponds to the prevailing temperature of the magma and to the pressure of water vapor. The portion of such a stratum near the volcanic neck will be at a high temperature, and the water in this portion will be in the form of steam; the cooler portions farther removed will contain liquid water, and be-

[7] T. G. BONNEY, *Volcanoes*, p. 24. The Science Series. G. P. Putnam's Sons, 1899.
[8] J. JOHNSTON and L. H. ADAMS. Journ. Geol. **22**: 1–15. 1914.

tween will be a surface at which the water is boiling. The location of this zone of boiling will be determined by the hydrostatic head of the water; if the head is about 3000 feet, the hydrostatic head will be about 100 atmospheres, and the zone of boiling will be removed to a region in which the temperature is about 310°.

When the magma crystallizes, the water dissolved in it at a pressure of 100 atmospheres will be concentrated, and the pressure may increase to a high value, as previously explained. If eruption, with release of pressure, takes place, we have the water, absorbed under a pressure of 100 atmospheres, being released under a pressure many times 100 atmospheres. The crystallization may take place at some distance from the point of entry of the water, under conditions such that the back pressure developed by the crystallizing liquid does not reach the porous strata which were the source of the water, or the suddenness with which the pressure is developed may be such that the tortuous channels in the porous strata offer a greater resistance to its release than does the overlying crust or lava column. It is highly probable that if such lava were to be forced into the water-saturated porous strata it would effectually seal itself by rapid cooling in the pore spaces.

The solubility of water in a silicate melt at a given pressure of water vapor will depend largely on the temperature, and it is to be expected that the solubility will increase with decreasing temperature, for the same reasons that gases are more soluble in cold water than in hot water. If an undercooled silicate mixture, that is, a mixture which had remained liquid altho it had cooled below the temperature at which crystallization should have taken place, were to come into contact with water vapor, say at a pressure of water vapor of 100 atmospheres as before, it would probably take up a much larger quantity of water than at a high temperature. Reference to the curve *ay* in figure 1, C will illustrate this point.

When the mixture of composition *y* is cooled, at T_y its vapor pressure is 5.1 atmospheres; if it be undercooled to T_y', its vapor pressure will fall to 4 atmospheres. If a mixture richer in water is undercooled, its pressure will fall to 4 atmospheres at a lower temperature, T_y''. Similarly, the pressure of 4 atmospheres will correspond to progressively lower temperature for mixtures of increasingly greater water content. If, now, liquid KNO_3 be undercooled to T_y'', under a water-vapor pressure of 4 atmospheres it will dissolve not the amount of water it would have dissolved at its saturation temperature T_y, but the larger amount corresponding to the mixture whose melting point

is T_y''. If crystallization be now induced, there will be a sudden development of a pressure, corresponding to the saturation pressure at T_y''; the water introduced into the melt at a pressure head of 4 atmospheres will be released at a much higher pressure, in this case about 11 atmospheres. If an undercooled magma were to come into contact with percolating waters, or the vapor generated therefrom, as previously explained, a similar introduction of water at a low pressure might take place. Introduction of this water might of itself induce crystallization in virtue of the lowered viscosity of the resulting magmatic solution, and it is conceivable that the result would be a sudden and violent outburst of steam and ash, at a comparatively low temperature.

SUMMARY

It has been shown that when a system composed of volatile and non-volatile components such as water and KNO_3 is cooled, crystallization will take place at a temperature lower than the freezing point of the pure non-volatile salt by an amount corresponding to the amount of volatile material present, and that the corresponding three-phase pressure increases rapidly as the temperature is lowered from the melting point of the salt. This increase is rapid whether measured in terms of the decrease in temperature of the three-phase equilibrium or in terms of the content of volatile material in the solution. From the latter fact it follows that in systems of the type of magmas, in which the non-volatile material is composed of such substances as the silicates, and in which the pressure required to retain any considerable proportion of water in solution must be large, a comparatively small amount of crystallization will result in a large increase in pressure. When a magma containing water cools, with consequent crystallization and development of high pressure, under an incompetent crust. a release of pressure will take place, which may be catastrophic in violence or take the form of a succession of mildly explosive outbursts. In case the magma cools under a competent crust the pressure will rise to a maximum, and then decrease, probably without at any time showing critical phenomena.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

BIOLOGICAL SOCIETY[1]

622ND MEETING

The 622nd meeting was held in the lecture hall of the Cosmos Club, on March 5, 1921 at 8 p.m. Vice President A. S. HITCHCOCK presided, and 32 persons were present. Upon recommendation of the Council Mr. M. A. MURRAY was elected to membership.

Brief notes

Mr. IVAR TIDESTROM exhibited two books. One was 202 years old, had seen constant usage, and was still in excellent condition; the second book, somewhat more than a year old, was in poor condition, both as to binding and the printed pages. The first book illustrated the durability of rag paper as compared with the pulp paper now commonly used even in reference works. DR. PAUL BARTSCH cited the deterioration of a book lying exposed from Saturday to Monday.

Dr. H. C. OBERHOLSER stated that the whistling swan, which had returned to nearby waters for four or five years past, after an absence of twenty years, were seen this last winter in increasing numbers. Dr. PAUL BARTSCH stated that Holboell's Grebe had been observed recently in the Tidal Basin; also that nineteen species of spring flowers had been reported at a recent meeting of the Wild Flower Preservation Society.

Formal program

H. M. HALL: *The synthetic method of botanical taxonomy.*

Botanical taxonomy has not much to its credit in the way of past achievements. At present it is at a nearly static or stationary stage in its evolution. In order to make it dynamic and progressive more attention should be paid to three phases of the subject.

(1) The development of a philosophic aspect. Relationships of phylogeny should be taken as the guiding principle in all taxonomic work. Analytical methods now employed should be combined with synthetic methods having as their aim the organization of these small units into larger natural assemblages, the data for such work to be obtained from comparative morphology, paleontology, ontogeny, and geographic distribution.

(2) The development of new methods. The present observational descriptive, and qualitative methods may well be replaced by methods that are experimental, quantitative and exact, thus elevating systematic botany to the stage of a true science.

(3) The development of a new method for the expression of results in a concise and readily intelligible manner. The use of diagrams to illustrate phylogeny is advised. More important is the development of a system of nomenclature that will express both the names of plants and their relationships. It is therefore recommended that the term "species" be used in the original comprehensive sense, that only these inclusive units or true species,

[1] Reports for the 627th and 628th meetings were published in this JOURNAL 12: 188–191. 1922.

be given binomials, that the principal subdivisions be treated as subspecies or varieties, and that still smaller units, such as those of the geneticist or other specialist, be treated in any other manner that meets the special requirements. In this way the number of species will be kept within reasonable bounds, the varietal category will provide for those who desire to go one step farther. and the recognition of even the smallest possible unit will not be excluded.

The paper was illustrated by lantern slides of plants, and tables showing the application of the suggestions which were made. The paper was discussed by Major E. A. GOLDMAN and Drs. P. BARTSCH, T. S. PALMER, F. W. COVILLE, and W. E. SAFFORD.

623RD MEETING

The 623rd meeting was held March 19, 1921 at 8:10 p.m., in the lecture hall of the Cosmos Club. President HOLLISTER was in the chair and 50 persons were present.

Informal communication

Dr. F. H. KNOWLTON stated that during the last ten years, for three of the spring months, continuously during the daylight hours a cardinal would fight his reflection in the windows of the speaker's house. The bird has been known to launch himself at the windows 26 times in five minutes. It is not known that it is the same bird which has been under observation during these years.

Formal program

F. H. KNOWLTON: *The flora of some newly discovered beds in southern Colorado.*

For fifty years highly fossiliferous deposits have been known in the Tertiary lake beds of Florissant, Colorado. Insects, plants, and birds, fish and shells are preserved with remarkable fidelity in the volcanic ashes and mud filling the lake. Other similar deposits have been found in Colorado, the largest near Creede. Among the plants found are pines, firs, grape, currant, poplars, flowers and fruit believed to be a raspberry, etc. Specimens were shown in the thin papery shales into which the rock breaks up. The paper was discussed by Messrs. ROHWER, HOPKINS, and HITCHCOCK.

H. C. OBERHOLSER: *The breeding water fowl of the Great Plains region.*

For several years the breeding grounds of water fowl in the United States were studied by the Biological Survey to secure data for the administration of game protection laws. The greatest breeding ground in the United States is in the State of Nebraska and the States northerly from it. Still greater areas exist in Canada. For many years the water fowl suffered from the draining of their feeding and breeding grounds, and by killing for sport and the market. Tens of millions of birds were sacrificed annually. Dr. Oberholser described and illustrated with lantern slides many of the lakes of the region used as breeding grounds of water fowl, and nests and birds were shown of several of the species. The paper was discussed by Dr. SHUFELDT.

624TH MEETING

The 624th meeting was held jointly with the WASHINGTON ACADEMY OF SCIENCES on April 2, 1921, in the lecture hall of the Cosmos Club, at 8:15 p.m. ALFRED H. BROOKS, President of the ACADEMY presided, and 75 persons were present.

Dr. A. D. HOPKINS, Retiring President of the Biological Society, delivered an address on *Intercontinental problems in natural and artificial distribution of plants*. An extended abstract of Dr. Hopkin's paper has been published in the JOURNAL OF THE ACADEMY.[1]

A. A. DOOLITTLE, *Recording Secretary.*

625TH MEETING

The 625th meeting of the Biological Society of Washington was held on April 16, 1921 in the lecture hall of the Cosmos Club, at 8:15 p.m. President HOLLISTER was in the chair and 66 persons were present.

Informal communications

H. C. OBERHOLSER: *A note on Miss M. T. Cooke's* Birds of the Washington Region, *published by the Society.*

Formal program

F. C. LINCOLN: *The Fall migration of ducks from Lake Scugog, Ontario.* Interesting results have been obtained from the work on the Bureau of Biological Survey in banding wild ducks trapped at Lake Scugog, Ontario. Last summer about 225 ducks were banded, mostly mallards and black ducks, with a few blue-winged teal and ringnecks. The Biological Survey has already received reports of the killing of over 35 of these ducks or about 16 per cent. Some were killed close to Lake Scugog, but others were from such distances as to clearly indicate the route these birds travel on their pilgrimage to the Gulf Coast. In the Mississippi Valley bands were returned from points in Ohio, Indiana, Kentucky, Tennessee, Arkansas, Mississippi, Louisiana and Texas. On the Atlantic coast no birds were reported from regions north of Chesapeake Bay, but south of this point the route is well connected, showing that these birds migrate in a southeasterly direction across the Alleghanies to the Atlantic coast.

Bands have been returned from Virginia, North and South Carolina, and Florida. The most interesting note was received through the State Department from the American consul on the island of Trinidad. The band had been placed on a blue-winged teal at Lake Scugog on September 24, 1920, and was recovered through a local hunter near Port of Spain, Trinidad, on December 9. (Author's abstract.)

The paper was discussed by Dr. A. S. HITCHCOCK.

E. W. NELSON: *Alaska and the reindeer industry.*

THOS. E. SNYDER, *Recording Secretary pro tem.*

626TH MEETING

The 626th regular meeting was held April 30, 1921, in the lecture hall of the Cosmos Club, at 8:15 p.m. President HOLLISTER was in the chair and 51 persons were present.

Informal communications

M. W. LYON: *Note on buffalo or bison raising.* This note was illustrated with a lantern slide of a carcass of a pure bison calf exhibited in front of a restaurant in South Bend, Indiana.

T. S. PALMER: *Note on the status of bison in the United States.* One large herd which was becoming unprofitable was disposed of by letting sportsmen shoot the animals at $250 per head. There are a thousand head on the market

[1] This JOURNAL 11: 223–227, 227–229. May 19, 1921.

in South Dakota. In New Hampshire they are occasionally on sale. There are two herds in Oklahoma with occasional sales. There were 8000 bison in the United States last year.

Dr. R. E. COKER exhibited copies of the new *Journal of Ecology*, which is a continuation of *Plant World*, but whose scope is to include both plants and animals.

Dr. PAUL BARTSCH referred to the column in the *Washington Herald* entitled Scientific Notes and Comments. A motion approving the column was carried.

Dr. C. C. ADAMS, Director of the Roosevelt Wild Life Experiment Station, spoke of the inception of the movement to perpetuate the memory of Theodore Roosevelt. The station established is a research station.

Formal program

J. N. ROSE: *Rediscovery of a remarkable cactus from Haiti.* For more than a century a cactus growing in Haiti has been known only from a drawing in the British Museum over the title *Cactus caniculatus*. No additional information was obtained until 1917 when a specimen was brought to this country by Dr. PAUL BARTSCH. Later Dr. C. G. ABBOT visited the region, and made complete field observations and collections, so that the plant is now pretty well known. A monograph of the species had been prepared in which the species is redescribed as *Neoabbotia caniculatus*. Some remarkable features are that it is the largest known cactus and its blossoms are in clusters. Photographs of the plant were exhibited. The paper was discussed by Dr. LYON and Dr. BARTSCH.

JOSEPH GRINNELL: *The principle of rapid peering birds.* Some birds wait for their prey to come within striking distance, others are on the constant search. The movement of an object quickly catches the attention of an observer. Similarly an observer changing his position brings out relative position, perspective, and recognition of objects. Thus some birds, pressed by necessity, have developed in the extreme the habit of rapidly changing position, peering in many directions, to secure food required for existence.

The paper was discussed by Drs. LYON and BARTSCH.

T. S. PALMER: *Notes on some parrots imported into the United States.* Of the 500 or more species of parrots now known, only 2 are natives of the United States and none of Europe. Thus they were practically unknown to the ancients. The knowledge of parrots is, therefore, an index to exploring activity. Columbus took the first American parrot to Spain in 1493. The first importation was at an early, though unknown date. Since then the United States has become one of the best parrot markets. The zoological parks contain the best collections, and have rare and some now extinct parrots on exhibition. The national Zoological Park has about 35 species. At times 75 or 80 species have been on exhibit at one time in New York and Philadelphia. The London Zoological Gardens have about 125 species.

The parrots imported in largest numbers are: the Amazons; certain species from Mexico and from Cuba; the Grass Parrakeet from Australia; and the Gray Parrot from Africa. The Amazons and the Gray Parrots are popular on account of their ability to talk. In 1904 more than 17,000 parrots were imported. This year more than 4,000 have already (April) reached San Francisco.

Few parrots are raised in this country though in Europe they are quite freely raised in captivity. The habits of parrots, and even their anatomy, are still not well known. Probably a dozen West Indian parrots have become extinct, and our Carolinian Parrakeet is confined to Florida and is almost extinct. The desirability of immediate further study is obvious.

E. A. GOLDMAN: *Rats in the War Zone.* Rats infested the whole war area, and their relation to epidemic diseases was early recognized. The speaker was commissioned as an officer to study and solve the problems presented by rats. Their holes, burrows, and paths were everywhere. German trenches were infested and many rat-catching devices were found in them. Rats were troublesome in disturbing sleeping soldiers, destroying supplies, eating and spoiling food, and as potential carriers and disseminators of disease.

Food was arriving in greater quantities that it could be cared for. Under the boards or litter upon which the cases of food were stacked, rats found shelter and opportunity to breed. Trapping was the chief means for control, but poisoning with squills was also effective. In food warehouses and trenches the control was reasonably adequate.

Rats bred rapidly. Females averaged 7.3 embryos. The number was as few as 3 and as great as 17. The principal species was the brown rat. Black rats were sometimes found where there were few brown rats to contend with. After the trenches were evacuated, foxes, weasels, cats and other predatory animals did much to eliminate rats, but many followed the men.

Many lantern slides were shown depicting the conditions which favored rats, their work, the methods of trapping, and some of the means of insulating against rats, both in the Allied and German lines.

A. A. DOOLITTLE, *Recording Secretary.*

BOTANICAL SOCIETY

153RD MEETING

The 153rd meeting was held in the Assembly Hall of the Cosmos Club at 8 p.m., October 4, 1921, with President CHAMBLISS in the chair and 106 persons present.

A. T. BRUMAN and FRANK G. O'DONNELL of the Federal Horticultural Board and ROBERT C. WRIGHT of the Office of Horticulture and Pomology were elected members of the Society.

An exhibit of dahlias was furnished by Mrs. WOLF, Dr. W. A. ORTON, Prof. J. B. S. NORTON, Dr. WM. E. SAFFORD and Miss FLORENCE THOMPSON. The regular program of the evening, consisting of a symposium on the dahlia, followed.

W. A. ORTON: *Group classification, climatic requirements and aims of dahlia breeders.*

The dahlia has been wonderfully improved by plant breeders until its range of form suggests the anemone, the water lily, the peony, the rose, and the chrysanthemum, as well as the types familiar to the public as dahlias.

Of the distinct groups of dahlias, the oldest is the Show. Then there are the Hybrid Show, Pompon, Fancy, Cactus, Hybrid Cactus, Decorative, Peony Duplex, Single, Collarette, Anemone, Star and Miniature Cactus.

The dahlia, a native of the tropics, can not withstand our northern winters. The roots must therefore be lifted and stored in sand in a cool cellar.

Those who are working for the further improvement of the Dahlia have still a large field of effort. In all cases, and particularly in the Cactus types, there is need for stronger, more upright stems, for greater freedom of flowering, and quality of producing strong, hardy roots. Some of the best varieties are such poor propagators that they always remain scarce and expensive.

J. B. S. NORTON: *History of the dahlia varieties.*

A tabulation of over 100 dahlia catalogues of 1921 shows about 5000 varieties now on the market. Nearly 5000 other named varieties grown in years past have now disappeared from cultivation. All these have developed in the gardens of Europe and America since the wild single dahlia was introduced from Mexico into European gardens a little over a hundred years ago.

The old-fashioned ball-shaped, regular forms, or show dahlias, were the first double kinds developed and had their day in the great dahlia shows of the second quarter of the nineteenth century. The minature ball forms, or pompons came in in the fifties. Some of them are probably the oldest varieties now in our gardens. The advent of the cactus dahlia type in 1873 led, through hybridization with the earlier kinds, to the many kinds of cactus, decorative and peony flowered dahlias which grace our gardens at the present time. The show dahlias, so desirable in the formal days of 1830 to 1850, have now almost disappeared from prize collections. Even the graceful cactus varieties which were the fashion at the beginning of the twentieth century are now far out-numbered by the great gloriously colored decoratives and hybrid cactus kinds which are now being produced more than any other types, especially in America.

W. E. SAFFORD: *Botany and chemistry of the dahlia* (illustrated).

In tracing the origin of the cultivated plants, it has been the custom to go back to the very earliest descriptions, noting the dates when they were written as well as those of their publication. Among early writers the rules of nomenclature now followed by botanists were not always observed. It was not uncommon for a botanist to ignore a well-established generic or specific name and substitute another more in accord with his own taste. Thus in 1809 Willdenow attempted to substitute Georgina for the generic name Dahlia established by the Spanish botanist Cavanilles in 1791 in honor of Andreas Dahl, a distinguished Swedish horticulturist, and finding the seedlings of the type of the genus to be exceedingly variable, he also changed its specific name, *pinnata* to *variabilis*. The variability points to a mixed ancestry, and it is quite possible that Cavanilles' type plant was a hybrid between two species or two distinct varieties or subspecies.

About the year 1576, more than two hundred years before the genus Dahlia was established by Cavanilles, Francisco Hernandez, a Spanish physician, sent by Philip II to New Spain to study its resources, observed many forms of Dahlias then cultivated in Mexico. It is interesting to note that at that early date types which are usually held to be modern creations, had already been developed. Dahlias were known to the Aztecs under the Nahuatl name *Acocoxochitl*, which may be translated "Cane-flower." This name was applied to them on account of their hollow, jointed stems, which bear a certain resemblance to the canes used as water pipes or tubes. Hernandez in calling attention to their beautiful and varied flowers, described certain forms with purple rays and yellow disks, and many others differing from one another in size and color; some white, others yellow, others red or purple, or white tinged with purple, or perhaps yellow tinged with red, and a great

many other kinds; in some cases with double or multiple whorls of ray flowers about the disk, or with the florets closely crowded into compact pompons or bunches (*Manipuli*). The roots he described as fleshy and succulent, and clustered like those of the classic asphodel. This description, although written about 1576, was first published in the Madrid edition of his works in 1750. In the Roman edition of 1790, however, are figured three forms of Dahlia, all of them with multiple florets suggesting forms now called the peony type, but differing in their foliage, the first two having leaves like those commonly called *Dahlia variabilis*, the last with divided leaves like those of *Dahlia glabrata*, or *D. gracilis*.

Four years later in addition to *Dahlia pinnata*, Cavanilles described and figured two other species, *Dahlia coccinea* and *Dahlia rosea*, "single flowered" forms differing from each other not only in color but also in the form and texture of the leaves. Some writers declare that these were merely two varieties of the same species, while others deny the possibility of this, declaring that *D. coccinea* and *D. rosea* cannot even be cross-pollinated to form hybrids.

The great revolution in Dahlia culture which led to the creation of the beautiful forms of today was brought about by the importation of *Dahlia juarezii* into Europe about the year 1864, a type of which is here presented, accompanied by a photograph of the well-known "Kalif" of our gardens, which seems to be a facsimile of it. *Dahlia juarezii* is the ancestor of all our cactus dahlias. It is interesting to note that the type of this species like that of *Dahlia pinnata*, was a "double form" and in all probability a hybrid. Recently, Mr. Wilson Popenoe, an explorer for the United States Department of Agriculture, came upon a single red Dahlia in the mountains of Guatemala with narrow rays reflexed or folded backward as in *Dahlia juarezii* and its descendents. This species, which I named *Dahlia popenovii* in honor of its collector, is in all probability the ancestor which gave to *Dahlia juarezii* and to all the cactus dahlias their tendency to fold back the margins of their florets.

On the same slide is shown *Dahlia maxonii*, another species from Guatemala, collected by Mr. William R. Maxon in the Department of Alta Verapaz in 1905. The latter species was for a time confused with *Dahlia imperialis*, from which it differs radically in its upright instead of pendent flowers, as well as in the form of its leaves. It is in all probability an ancestor of the hybrid *Dahlia excelsa*, the type of which was a cultivated plant with abnormally elongated disk-flowers resembling the so-called anemone-flowered types of our gardens.

Concerning the roots of the Dahlia, these were compared by early writers with those of the asphodel, which were also fleshy and grew in clusters. Attempts have been made to use the roots for food for cattle and pigs, but on account of the unpleasant taste they have been rejected. Instead of starch the roots contain a substance known chemically as inulin. From this a sugar known as levulose or fructose is obtained. This sugar is sixty per cent sweeter than cane sugar, but it has hitherto commanded such very high prices that it has not been of commerical importance. It crystallizes with great difficulty, and the expense has been chiefly due to the fact that it was necessary to use much alcohol in eliminating the water. Although this sugar crystallizes with difficulty, yet it can be utilized even in the form of syrup, especially at soda fountains, and as an ingredient for various drinks and desserts.

The Regular Meeting then adjourned and the Annual Meeting was held. Dr. W. E. SAFFORD was elected President, Dr. HOMER L. SHANTZ was elected Vice-President, Mr. ROY G. PIERCE was re-elected Recording Secretary, Mr. R. K. BEATTIE was re-elected Corresponding Secretary, and Dr. L. L. HARTER was re-elected Treasurer.

154TH MEETING

The 154th meeting was held in the Assembly Hall of the Cosmos Club at 8 p.m., November 1, 1921, with President SAFFORD in the chair, and 68 members and guests present. Among the distinguished guests were Professor ARTHUR A. JACZEWSKI, Director of the Institute of Mycology and Plant Pathology of Petrograd, and Prof. NICHOLAS I. VAVILOV, Director of the Institute of Bureau of Applied Botany and Plant Breeding at Petrograd. Mr. JAMES R. WEIR, whose name was presented at the October meeting, was voted into the Society.

Under *Brief notes and review of literature*, Mr. C. P. HARTLEY presented an exhibit of several interesting ears of corn, two with long silks retained and one a nubbin. One was peculiar in that the fine silk retained was attached to the kernels; the second showed that the first silks that protrude do not come from the extreme butt kernels, but from those slightly above the base of the stalk, differing from the popular conception; the third showed that the seed coat can develop without any starch or germ.

O. M. FREEMAN, of the Bureau of Plant Industry, exhibited two potted hepaticas, one in blossom, and the other without blossoms. The plant in blossom has been subjected to an artificial winter. In the experiment 6 pots had been used—3 had been chilled for 2 months, while the others had been kept at ordinary room temperature. Two weeks after being chilled they came into blossom. Prof. ARTHUR A. JACZEWSKI of Petrograd remarked that this chilling of plants to induce flowering was formerly a regular practice in Russia and that lilacs were brought out in blossom at Easter time.

The regular program of the evening consisted of an illustrated lecture by Mr. ROBERT S. YARD, Executive Secretary of the National Parks Association. A wonderful collection of colored views of some of our National Parks was shown, including some from the Yellowstone Glacier, Mount Rainier, Crater Lake, Yosemite, Sequoia and Rock Mountain National Parks. Of the 19 national parks all but 2 are in the United States. These include Mt. McKinley in Alaska and a volcano in Hawaii. Water power and irrigation interests were trying to encroach upon the public domain and to secure special privileges in the National Parks. The National Park Association was trying to crystallize public sentiment against the exploitation of these Parks.

ROY G. PIERCE, *Recording Secretary.*